

Domestic Mobile Satellite Systems in North America

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ABSTRACT

Telesat Mobile Inc.(TMI) and the American Mobile Satellite Corporation (AMSC) are authorized to provide mobile satellite services(MSS) in Canada and the U.S.A. respectively. They are developing compatible systems and are undertaking joint specification and procurement of spacecraft and ground segment with the aim of operational systems by late 1993. Early entry (Phase 1) mobile data services are offered in 1990 using space segment capacity leased from Inmarsat. This paper gives an overview of these domestic MSS with an emphasis on the TMI component of the MSAT system.

INTRODUCTION

Canada and the United States have long recognized the need for reliable mobile communication services to all areas of the continent.

There is an extensive need for improved and additional land mobile service communication capabilities. In both Canada and the United States, there are large coverage gaps in services provided by terrestrial systems.

There is also a need for improved aeronautical mobile communication services in all areas of North America and adjacent over-water areas. These needs extend to both safety and non-safety communications, and are analogous to the land mobile service needs discussed above. The ICAO Future Air Navigation Systems (FANS) Committee envisions aeronautical mobile safety communication evolving to the use of satellite services thus allowing a significant reduction of the present ground infrastructure.

Canada and the United States have begun initiatives to develop compatible mobile satellite service systems to serve aeronautical, land, and maritime users. These system developments are being pursued by Telesat Mobile Incorporated (TMI) and the American Mobile Satellite Corporation (AMSC) in Canada and the United States, respectively. The objective of these developments is to have a compatible overall system in which there are separate but similar spacecraft operated respectively by TMI and AMSC, with mutual backup. The companies are in the contract negotiation stage for the spacecraft procurement and have issued an RFP for the specification of the ground segment. These systems are planned to be in operation from late 1993.

SYSTEM DESCRIPTION

User Requirements

From the several market studies carried over the past few years to identify the types of services are required and the size of the market for a wide area mobile satellite system, the services identified include the following:

- (1) Mobile Radio Service (MRS) which provides voice and data communications between a mobile terminal and a base station or between mobile terminals in a closed user group.
- (2) Mobile Telephone Service (MTS) - a full duplex voice communications service which provides direct access for mobile terminals to the Public Switched Telephone Network (PSTN).
- (3) Mobile Data Service (MDS) - a service which provides a communications path for the bi-directional transfer of data between a mobile

terminal and a data hub station in a packet-switched mode.

(4) Aeronautical Service may be provided by some of the above categories, but it has its own international system definition (as described by ICAO's FANs committee) and is therefore categorized separately. Applications include Air Traffic Services (ATS), Aeronautical Operational Communications (AOC), Aeronautical Administrative Communications (AAC), and Aeronautical Public Correspondence (APC). Over Canada and the U.S., satellite aeronautical communications will be over MSAT; however, aircraft will be able to switch to international space segments.

Other services, such as Position Location Service, Wide Area Paging and Transportable Communications Services, will be provided as the needs are better defined.

Some services, such as those pertaining to safety of life and regularity of flight for aeronautical services (ATS and AOC) or distress and safety for maritime services, require higher priority than other communication services.

TMI estimates the potential demand for MSS services at 300,000 to 450,000 mobile terminals in Canada by the year 2000. Data is expected to constitute 50% to 60% of this potential demand. Personal communication via satellite is expected to start in the next few years and possibly to become the dominant market beyond the year 2000.

System Configuration

The service coverage area is the whole of the North American land mass and coastal waters up to the 300 km limit plus the islands of Hawaii and Puerto Rico. Optional coverage includes Mexico and the Caribbean, and the international flight information regions controlled by Canada and the U.S.A.

The system has been designed to serve a large number of users, each with low activity of an intermittent nature. The satellite resources (channels) are therefore best utilized by assigning them on a demand basis. The demand access capability is satisfied by a Priority Demand Assignment Multiple Access (PDAMA) system residing in the Group Controller (GC). Mobile

Earth Terminals (METs) can be connected among themselves, to base Feederlink Earth Stations (FESs), PSTN or data network subscribers (via a gateway FES), hence providing a flexible communication network.

The main elements of the system are:

(1) The space segment which includes the satellite and the Satellite Control Centre (SCC).

(2) The ground segment consisting of FESs (gateway, base, and hub stations), and METs.

(3) The Network Control System (NCS) which includes the Network Operating Centre (NOC) and Network Control Centre (NCC) housing the Group Controller (GC).

(4) A Signalling system to interconnect the elements of the system.

Communication with other networks will be done by the NOC.

The configuration of the MSAT system is shown in Figure 1.

The GC can allocate circuit capacity on a per call basis for voice and circuit-switched data. It can allocate a channel (or channels) to be used for packet-switched data under the control of the data hub. A MET typically places a call on a signalling channel (request channel). The GC uses a signalling channel (assignment or control channel) to assign a free communication channel to that MET and a FES. At the termination of the call the terminal relinquishes the communication channel which then becomes free for reassignment by the GC to another call. For AMS(R)S service frequency and power capacity will be allocated in distinct portions which will be used in channels consistent with ICAO SARPS.

The MSAT system will have multiple spot beams in order to increase the satellite EIRP, and to allow for frequency reuse since the available spectrum is limited.

Forward links from FESs will use SHF uplinks to the satellite and L-band downlinks from the satellite to the METs. In the other direction, reverse links from the METs will use L-band uplinks to the satellite and SHF downlinks from the satellite to the FESs. Thus all commun-

ications to and from the METs are at L-band (uplinks in 1631.5-1660.5 MHz and downlinks in 1530-1559 MHz, as allocated by WARC-MOB'87), while all transmission to and from the FESs and the network control centre will use 13/11 GHz uplinks and downlinks. In Canada 13 GHz band is allocated on a co-primary basis to Very High Capacity Microwave (VHCM) links. The 11 GHz band is also used by fixed terrestrial services. Therefore, effective use of SHF spectrum is also very important.

In the normal mode of operation, the uplink signals from 1.6 GHz band beams will have their frequencies translated at the satellite into the SHF downlink beam. Similarly, the uplink SHF channels will be translated in frequency to the 1.5 GHz band downlink. As well, a segment of these SHF channels will be cross-strapped to form a direct SHF-SHF link. These SHF-SHF links are intended mainly for signalling, data exchange among gateways, and for NCS communication purposes.

PROVISION OF SERVICES

The system operators have the capability to operate as common carriers, owning and operating the satellites and NCSs that provide priority demand assigned multiple access to satellite power and spectrum resources as explained below. As the single point switching and control centre, the NOC/NCC will assign these resources to the multiplicity of users in a flexible manner. End users could obtain service from service providers who may be institutionally independent of the space system operator.

The MSAT system will have "variable dynamic spectrum partitioning" capability which will allow flexibility in assigning spectrum to different services. This capability will allow the assignment of exclusive spectrum for aeronautical safety communication services which will be varied depending on need. In the event that peak AMSS (R) safety traffic is anticipated to exceed then allocated bandwidth, additional bandwidth and power will be made available on a realtime pre-emptive basis. The aeronautical operators will notify the MSAT NOCs ahead of time of their requirements to make sure that resources are available when required without having to preempt other services except in extreme situations.

Authorities responsible for aviation safety will arrange with the system operators for the operational capacity they require and will set up their own network using their own signalling characteristics, protocols and control channels. Their NOC/NCC(s) may operate independently of the MSAT NCS.

Air Traffic Services (ATS) which includes air traffic control, and Aeronautical Operational Control (AOC) are the only communications functions that comprise AMSS(R) with the right of priority and immediate preemptive access. Other aeronautical communications, Aeronautical Administrative Communications and Airline Passenger Correspondence have the same status as similar non-aeronautical communications. The control capability of the GCs will also enable priority access for non-aeronautical safety and emergency communications.

Communications other than aeronautical safety communication services will be provided to end users through a variety of service provider arrangements under the control of the NOC.

An MSS telephone subscriber may be served by his local telephone company or radio common carrier who may own a FES at the telephone exchange. When a call is placed by the vehicle or to the vehicle, the request will be relayed from the vehicle or FES through the satellite to a GC on a request channel. The GC will use the request channel to assign a communication channel pair to the vehicle and the FES. The call will then be set up by the exchange. When the "on hook" signal is received at the GC over the request channel, the communication channel pair will be returned to the pool of available channels for reassignment to another call.

A government agency, utility or large trucking company may set up its own network of feeder link earth stations for its direct call setup and communications with its vehicles. Operation of the network will require lock to the control channels of the GCs in order to comply with the requirement for priority and preemptive access for essential safety communication services.

SYSTEM PERFORMANCE REQUIREMENTS

For optimum utilization of the spectrum, most communications will be established using Single-Channel-Per-Carrier (SCPC), Frequency

Division Multiple Access (FDMA) with nominal 5 kHz channel spacing as compared with the wider 30 kHz channels adopted for most terrestrial systems. This 5 kHz channel requirement places a constraint on the possible speech coding/modulation techniques that can be used in MSAT. The baseline analog voice modulation scheme considered by TMI is Amplitude Companded Single Sideband (ACSSB) and the baseline digital version is 4.8 kbps Codebook-Excited Linear Predictive Coding (CELPC) using 16-QAM Trellis Coded Modulation. Other suitable coding/modulation techniques may be employed.

Voice performance is dependent on the inherent performance of the modulation schemes used, propagation characteristics of the links, noise and interference, the practical limits of the satellite RF power per voice channel as well as the practical limit of the earth terminal G/T's that can be achieved considering the dimensions of the vehicular antenna. Mobile Radio Service (MRS) voice channels will be designed to operate with an unfaded carrier-to-noise density (C/No) of around 51 dB-Hz at the L band. For users who do not experience shadowing, e.g. for aeronautical and marine applications, the C/No requirements may be relaxed by a few dBs.

For an MRS terminal with a G/T of -15 dB/K, these voice channel performance requirements translate into a satellite EIRP of around 30 dBW per voice channel for ACSSB, as shown in Table 1.

The G/T performance of the satellite at L-band has a significant impact on the coast of the mobile earth terminals. A reasonably high satellite G/T permits the operation of the METs will reasonable RF power levels. The MSAT satellite L-band G/T is specified at 2.8 dB/K.

Capacity of a first generation Canadian system should be high enough to serve, during the peak traffic period, at least 60 thousand equivalent voice users. Assuming voice activation with an activity factor of 0.4, traffic of 0.0106 Erlang per average user, and a grade of service of 2%, the 60,000 users translate into approximately 710 assigned channels, for voice traffic. Of course, the traffic will not be homogeneous--various channels and blocking rates will be used.

Since the actual distribution of users may not be known until some considerable time after the start

of service, the system has to be able to accommodate a concentration of users in some parts of coverage area. The space segment is being designed to allow redistribution of system capacity.

For the land mobile voice channel performance requirements, some tests have indicated that for ACSSB, the 51 dB-Hz may degrade to around 40 dB-Hz before the MRS channel becomes unusable. With the given noise budget, this translates into a downlink margin of about 10 dB. Signal level degradation for mobile terminals operating in the 1.5/1.6 GHz band is mostly due to multipath and blocking by obstacles, such as trees, and a full characterization of these will not be available until some time after the start of the service. The link margin required for a given grade of service may therefore have to be modified after the launch of the satellite to accommodate the blockage characteristics of a particular service area. Hence the space segment design will permit operation with some level differences among the active channels. Some places in the coverage area enjoy relatively high elevation angles and/or have little or no shadowing. For these areas, the link margin requirements could be reduced, hence lower satellite EIRP per channel would be needed. Further, other modulations requiring less EIRP's may be developed in the future.

MSAT SPACE SEGMENT

The size, power, and configuration of the MSAT satellites are determined by the performance requirements of the system. The spacecraft outlined in here is only one of several configurations being considered. It is taken as a baseline for system capacity and cost estimation.

The baseline configuration provides the coverage of the North American service area at L band by five beams with an Edge Of Coverage (EOC) gain of 32 dBi. Two other beams are included for Hawaii, Puerto Rico and Mexico. See Figure 2. Other configurations considered have as many as 11 beams. A single SHF transmit/receive beam serves to cover the combined Canadian-US service area, with an EOC gain of 25 dBi (Figure 2). The MSAT aggregate EIRPs for the basic area are approximately 55 dBW and 36 dBW for L-band and SHF, respectively.

To accommodate a variety of users with different requirements, hence different modulations, power levels, etc., the satellite will have wideband linear transponders i.e. there will be no channelization at the satellite. Intermodulation performance of the transponder is a key requirement. A minimum of 22 dB C/Im is required for the fully loaded transponder. Another important parameter is the interbeam co-channel isolation which determines the minimum frequency reuse factor achievable. Co-channel C/Is of 20 dB in the forward link and 22 dB in the reverse link have been specified.

Because the same 1.5/1.6 GHz spectrum is sought by many administrations and international organizations, there is no guarantee that the satellite will have a contiguous segment of spectrum to meet its needs. It is most likely that several pieces of spectrum will be available all across the band after coordination with other users of the band. The system therefore, should have enough flexibility such that any piece of spectrum in the band can be switched into any beam. This permits an assignment of system capacity in multiples of a basic unit of spectrum among the beams, by means of a ground commandable switching network.

The main space segment characteristics are summarized in Table 2.

MSAT GROUND SEGMENT

The major components of the ground segment are the Feederlink Earth Stations (Gateway, Base, and Data Hub) and the Mobile Earth Terminals.

The Gateway FESs will interface with the PSTN to allow for communication between users and the PSTN subscribers. The gateway FES will support voice and data transmissions. For PSTN data services, such as Data-Route and Datapac, protocol translators will be required at the gateways. The gateways will operate in the 13/11 GHz bands and they will be located at sites across Canada to ensure optimum usage of the terrestrial and satellite networks aimed at minimizing user cost.

The Base FESs are defined as the dispatch centres or private fixed earth stations for user groups subscribing to MRS or other private services. It is assumed that every MRS user group will consist of at least one Base FES and a

number of mobile earth terminals. It is expected that up to 95 percent of MRS traffic will be between Base FESs and mobile terminals, and only 5% will be MET-to-MET. The base FESs will operate in the 13/11 GHz bands.

The Mobile Earth Terminals will be under complete control by the GC. They will operate primarily in the full-duplex mode, and the transceivers will have a frequency agile design. The terminal will operate in the 1.5/1.6 GHz band. It will have a DAMA processor which will enable it to receive and respond to instructions from the GC communicated via the signalling channels. For positive control, the MET will have a signalling channel receiver (SCR) separate from the main communication channel receiver so that it will receive the signalling channel at all times (even when transmitting). This offers several advantages including:

- the availability of a continuous signal for mobile antenna tracking and power control;
- positive derivation of frequency from a common frequency reference;
- access denial for terminals not meeting performance specifications;
- support of specialized network features such as display of calling number, call waiting etc.
- the means to continuously control the MET for reassigning to open channels or for preemption.

The MET will not be able to transmit unless it is locked to the control channel. An option that may be required of some classes of METs will be the incorporation of built-in sensors that measure key performance parameters that could be read out on command over the control channel by the GC.

TMI expects that the majority of METs will be integrated voice and data terminals. That is a single terminal will be capable of providing a combination of mobile voice, mobile telephone, and mobile data services

Antenna gain of the mobile terminals has a direct effect on one of the most cost-sensitive parameters of the system - the downlink (satellite) EIRP. Design and qualification of a cost-

effective high gain vehicular antenna which is acceptable by the user community from a cost, performance, and an esthetic point of view is therefore of considerable importance.

NETWORK CONTROL SYSTEM

The Network Control System will be the single point control for all system operating functions except aviation safety. The functions include:

- System frequency reference
- Communication channel assignment
- Priority assignment of channels
- Network performance monitoring
- User equipment performance monitoring
- Turn-off of malfunctioning user equipments
- Preemption of bandwidth needed for safety reassignment
- Recording of time, bandwidth and power used per call
- Recordkeeping and billing.

The NOC will be responsible for overall supervision, maintenance and long-term resource planning of the system. It will communicate directly with the GCs and the Aviation NOCs in order to receive information concerning traffic statistics and AMS(R)S needs. The NOC will compute the partition between voice, data, and signalling channels to optimize performance and will execute the partitioning required by the aviation safety system. Furthermore, it will be responsible for optimizing the routing tables used by the GC to route the MTS calls to the proper gateway stations. This information will be transmitted to the GC. The NOC will also gather billing information from the GC and the gateways.

The Group Controller coordinates, controls, and maintains the activities within different Control Groups, with particular emphasis on the short-term activities and events. The principal objectives of the GC are to achieve maximum channel availability in performing these functions, and in conjunction with the NOC to make the best use of the system resources. An efficient signalling system is required which can use the minimum number of channels while still providing an acceptable performance, such as call set up times. The GC will also transmit frequency and timing information to other network entities.

The Canadian GC(s) will operate a network consisting of approximately 80,000 to 160,000 users at the point of system saturation for the first generation system. It will be connected to all FESs and METs via packet-switched signalling channels. The United States GCs must accommodate an even larger number of users and will have functionally similar signalling channels.

All communication control functions associated with the network, such as call processing, must be performed by a set of highly reliable fault-tolerant computers compatible with the other network elements to ensure maximum system reliability.

The Network Control System is described in detail in companion papers elsewhere in this conference.

PHASE 1 MSS SYSTEMS

Phase 1 Mobile Data Services will be introduced in 1990 by both TMI and AMSC, using leased space segment capacity, in order to build up a customer base for future MSAT services and to gain experience in the operation of a domestic MSS system. TMI's system, which went into operation in May 1990, is mainly a two-way store and forward digital messaging system. It is capable of collecting regular position reports (e.g. every 15 minutes) and exchanging a number of messages each day with up to 6,000 vehicles in the initial implementation. Details of TMI's phase 1 MDS system are given in a companion paper in this session. The AMSC Phase 1 MDS system, commencing later in 1990, is also described in a paper in this session. TMI is also planning on a Phase 1 Mobile Voice System using Inmarsat's space segment beginning in 1991.

CONCLUSION

This paper has described the baseline concept of the MSAT system that will provide a variety of mobile satellite services beginning late 1993. The North American MSS systems are being developed jointly by TMI of Canada and AMSC of the U.S.A. Procurement of the space segment hardware will commence in mid 1990, and that of the ground segment hardware in mid 1991. The Phase 1 MSS, offering mobile data services via leased space segment, started in May 1990.

PARAMETER	UNIT	FORWARD LINK	REVERSE LINK
UPLINK		4.7m FES Ant. to Mobile	Mobile to 4.7m FES Ant.
Frequency	MHz	13200	1650
Uplink EIRP/Voice Act. Carr.	dBW	47.2	14.5
Path Loss	dB	206.8	188.7
Satellite G/T	dB/K	-3	2.8
Req'd Flux Density/Voice Carr.	dBW/m ²	-115.7	-148.4
C/No Thermal	dB-Hz	66.0	57.2
DOWNLINK			
Frequency	MHz	1545	11300
Req'd EIRP/Voice Act. Carr.	dBW	30.0	8.6
Path Loss	dB	188.2	205.8
Receive Terminal G/T	dB/K	-15.0	28.2
C/No Thermal	dB-Hz	55.4	59.6
INTERFERENCE (C/I)			
Intermod & Energy Spread			
Uplink	dB	32	30
Downlink	dB	22	22
Interbeam Co-channel			
Uplink (Incl. interstitial spac.	dB		
Downlink (Incl. interstitial sp	dB	25	27
Other Sources			
Total Interference (C/I)	dB	23.5	22.7
Total C/I _o	dB	18.4	18.3
Total Unfaded C/No+I _o	dB-Hz	53.1	53.1
	dB-Hz	51.0	51.0

Table 1. Reference Circuit Link Budgets for ACSSB Voice

Orbit location	106.5°W, Canadian 62°W, 101°W, 134°W U.S.
Satellite class	2,500 kg
Payload mass	350 kg
Payload power	2.0 kW
Frequency bands	RX 1631.5-1660.5 MHz TX 1530-1559 MHz
Transponder bandwidth	29 MHz
Number of beams	5 at L-band (+option for Mexico) 1 North American SHF
Polarization	RHCP for L band linear VP Receive HP Transmit for SHF
Antenna size	two 5m reflectors for L-band
EOC G/T	2.8 dB/K 1.6 GHz -3 dB/K SHF
Eclipse protection	50% of busy-hour traffic
Service life	10 years minimum

Table 2. Space Segment Characteristics

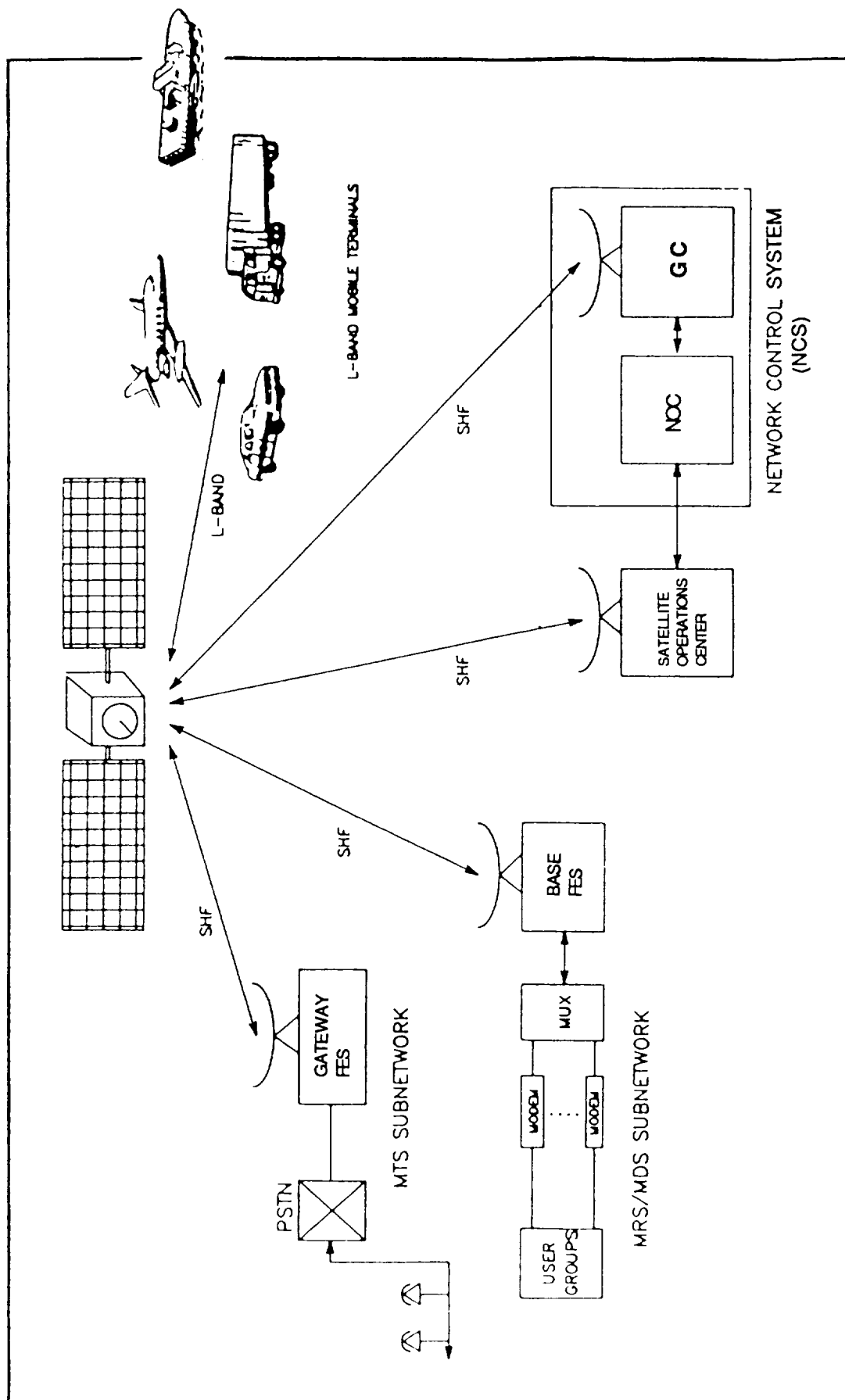


FIGURE 1: SYSTEM CONFIGURATION

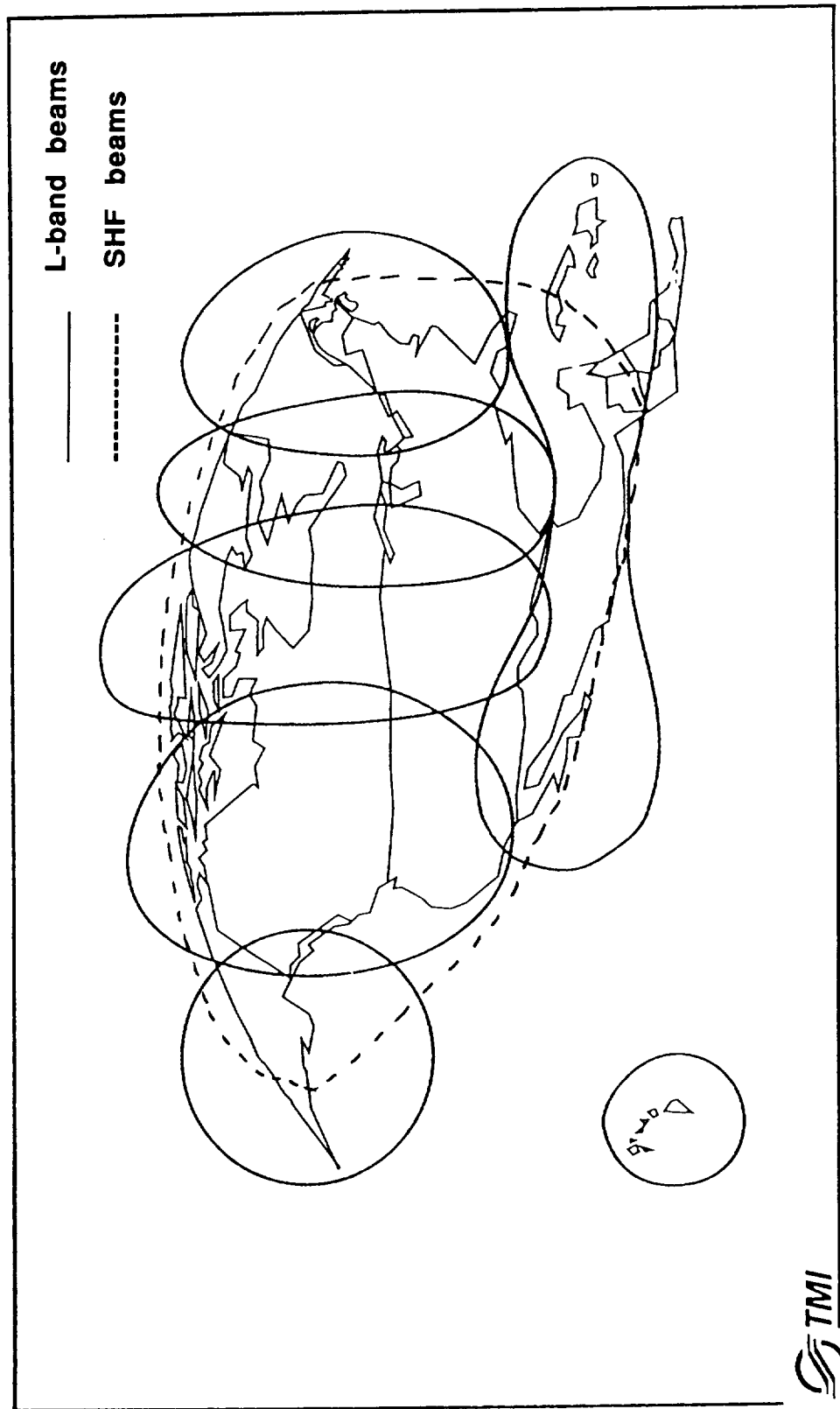


Figure 2 L-band beam coverage pattern